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Design of Battle Simulations for Command and Staff Training

Robert E. Solick and James W. Lussier

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Systems Research Laboratory

U. S. Army

Research Institute for the Behavioral and Social Sciences

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This report summarizes findings from 10 years of research at the Army Research Institute Fort Leavenworth Field Unit on command and staff training with automated battle simulations. Topics include design issues related to training objectives, performance measurement, simulation requirements, user interfaces, and workload estimation. This assessment of lessons learned provides guidance to developers of the next generation of battle simulations.

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Design of Battle Simulations for Command and Staff Training

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FOREWORD

The Fort Leavenworth Field Unit of the Army Research Institute for the Behavioral and Social Sciences (ARI) supports the Combined Arms Center with research and development on combined arms operations and command group training. With the fielding of the first fully automated systems for command and staff training, the simulation development community is engaged in assessing lessons from previous efforts while embarking on the automation of staff training at high echelons.

As part of Research Task 1.3.3., "Improved Methods for Command Group Training," the report summarizes 10 years of research on issues from which design criteria may be derived for the new generation of training systems. The report was prepared under a Memorandum of Understanding, dated 30 May 1985, between the Combined Arms Training Activity (CATA) and the Army Research Institute. Recommendations from the report, which were briefed to the Training Simulations System Manager of CATA on 30 January 1987, will be incorporated in requirements for new simulations.

Edgar M Johnson

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DESIGN OF BATTLE SIMULATIONS FOR COMMAND AND STAFF TRAINING

EXECUTIVE SUMMARY

Requirement:

To provide design criteria for the next generation of automated battle simulation based on behavioral research on command and staff training.

Procedure:

A systems-approach-to-training model was adapted to the context of command and staff training with automated battle simulations. Results of research on each of the major components of the model were discussed and related to design goals and criteria that should be considered in the development of future training systems.

Findings:

Excessive support staff requirements, lack of system support for scenario development, lack of system control over information and intelligence and lack of performance measurement capabilities were found to be recurrent deficiencies in previously developed systems. A new requirement for training with tactical data systems may ameliorate some of these deficiencies while adding to the complexity of system software. Proposed solutions include developing a systemic model to minimize support requirements and using on-line data capturing techniques for performance measurement.

Utilization of Findings:

Application of these lessons learned will allow developers of training systems to avoid previous problems in user acceptance of systems. Incorporation of the recommendations in the new generation of training systems will reduce support costs and increase the ability of such systems to assess and address training needs.

DESIGN OF BATTLE SIMULATIONS FOR COMMAND AND STAFF TRAINING

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DESIGN OF BATTLE SIMULATIONS FOR COMMAND AND STAFF TRAINING

SECTION 1. INTRODUCTION

Simulations designed to train Army commanders and staffs in planning and conducting military operations have reached a turning point in their development. Manual simulations at lower echelons (battalion and brigade) have been supplemented and to some extent supplanted by computer-assisted simulations. Currently, the Army is fielding the first operational fully-automated simulations. The availability of low-cost high-performance computer systems and high-fidelity combat models has made it possible to design the next generation of training devices based upon the desired performance capabilities of the system rather than being overly constrained by limitations in technology. The simulation development community is now engaged in assessing the lessons learned in previous development efforts while embarking upon a much more ambitious plan to automate staff training at high echelons.

The Army Research Institute (ARI) Field Unit at Fort Leavenworth has been participating in battle simulation research and development for ten years, including work on CAMMS, CATTS, ARTBASS, and MACE.[1] During that decade, an accumulation of experience and research findings has developed that can be brought to bear upon the design of the next generation of simulations. This report documents some of the major training issues and design goals that should be considered in battle simulation development.

Background

The basic features of a systems approach to training are depicted in Figure 1. The training objectives are comprised of a list of tasks that the trainees should perform, a list of conditions under which they should be performed, and a set of standards for performance. In the case of battle simulations, the training system consists of a simulated battlefield situation that should be designed to require performance of the tasks included in the training objectives (or a subset of those tasks) while simulating the conditions under which those tasks would be required. Figure 1 emphasizes the role of feedback in the conduct of training and in determining which objectives require additional training.

Feedback is critical for effective learning. A major reason to adopt a simulation-based training approach is to increase the amount of task feedback obtained by the trainees. Command groups receive this feedback from the simulation, from subordinates, from superiors, and from other members of the staff.

1

The Combined Arms Map Maneuver System, the Combined Arms Tactical Training Simulation, and the Army Training Battle Simulation System, respectively. MACE (not an acronym) has been renamed BABAS - Battalion Battle Simulation.

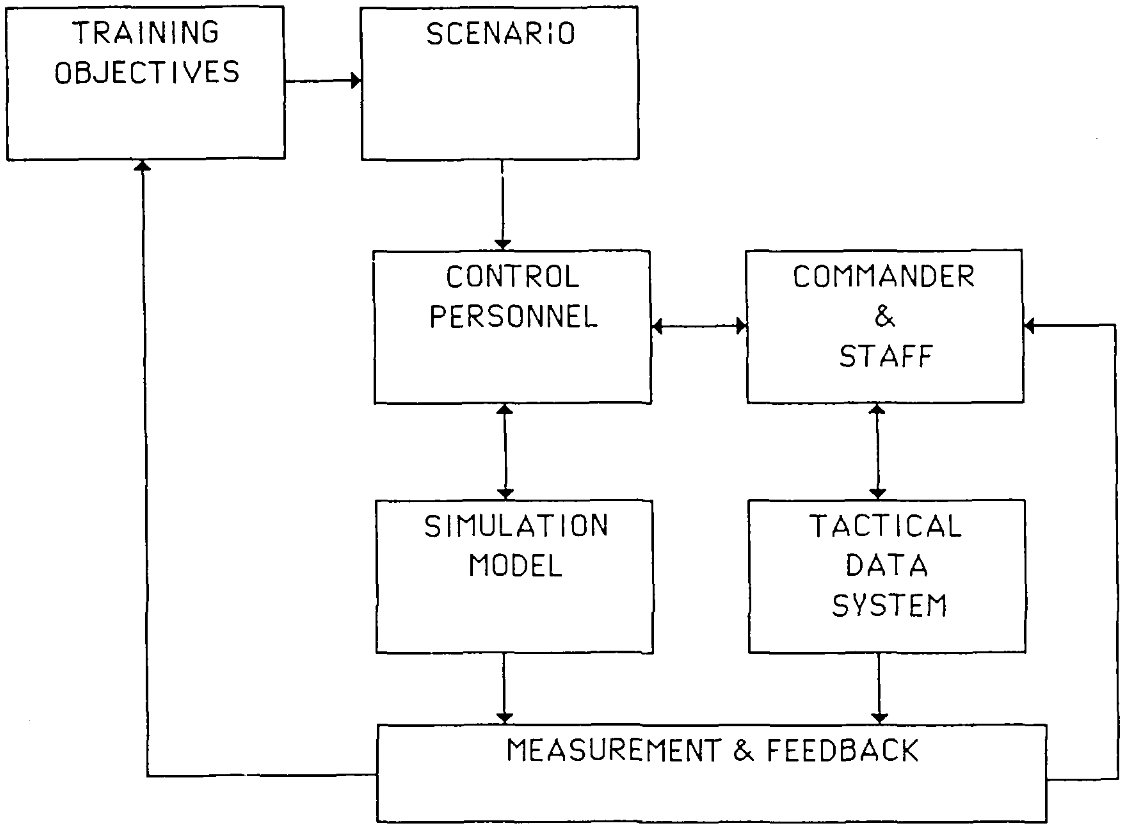

Figure 1. A typical command staff training configuration.

Unfortunately, the feedback received is not as immediate nor as accurate as in simulations designed to train simple judgmental and motor skills, such as flight simulations. Instead, the root causes of problems are often unknown. In addition, inappropriate decisions and actions may sometimes lead to success, while appropriate behavior may occasionally lead to failure. For these reasons, the intrinsic feedback must be supplemented with an extrinsic assessment of performance. Furthermore, this measurement requirement may require modifications in the design of the training system.

Figure 1 shows how the general training model is typically applied to command staff training. A set of training objectives, based upon a prior assessment of the training needs of a command group, is used to select and embellish a scenario which will require the staff to perform the tasks in the set. The training objectives are also used to develop a plan for observation and measurement of staff performance. The scenario consists of a mission, resources sufficient to accomplish the mission, an opponent, a recent history of the conflict, a piece of terrain, and an intelligence build-up giving clues to the size, location, and probable course of action of the opponent. The basic features of the scenario are used by the control personnel to prepare an operations order for delivery to the training audience (the commander and staff being trained), to establish initial conditions in the simulation model and, in units equipped with tactical data systems, to initialize their data bases as well.

During an exercise, the control personnel simulate higher, lower, and adjacent headquarters; they translate command group directives into computer input formats; they translate computer output into tactical messages; they keep themselves apprised of the tactical situation and of the status of resources in their functional area; they supply additional model control input for the opposing force; and they participate in observation and measurement of staff performance.

The commander and staff of the group being trained analyze their mission, develop a plan, deliver an operations order, and execute their plan. With the advent of tactical data systems, the staff consults the system for information, files information from subordinate elements, and provides standard operating procedure (SOP) reports via digital transmission. The control personnel can also file SOP reports using the tactical data systems, and, if properly equipped, can access the information residing there to determine what picture of the battle is currently available to the members of the training audience.

Organization of Report

Figure 2 shows some of the steps involved in developing a simulation-based training system. The organization of this report is aligned with the steps in the figure. Although other characterizations are possible, the steps indicated affect the most basic training decisions - who is trained, what they are trained to do, how their progress is measured - and the most basic design decisions - what modeling techniques are used, how much automated support is provided, how large a support staff is required, and what hardware capabilities are needed to accommodate the model and the users of the system.

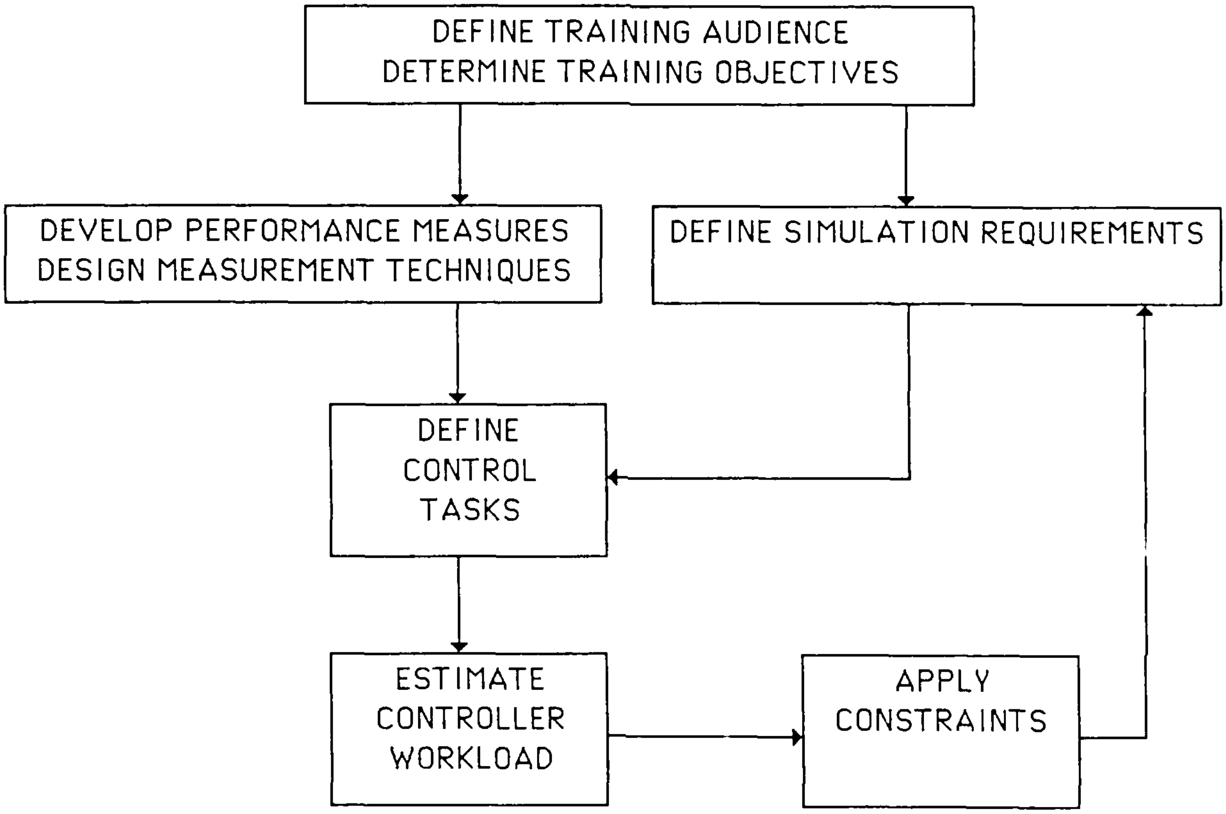

Figure 2. Steps in designing a battle simulation.

The determination of who should be trained in a battle simulation and of what they should be trained to do is discussed in Section 2 of this report. The commonplace assumption that every member of the staff group should be trained simultaneously on all of their combat tasks is critically examined.

The influence of performance assessment techniques upon system design is emphasized in Section 3. Performance measurement has been neglected in existing simulations. Usually, the more promising approaches to objective, automated measurement and feedback cannot be retroactively incorporated.

Simulation design and fidelity issues are considered in Section 4. A comprehensive analysis of modeling, system usage, and support requirements is recommended.

The determination of control personnel tasks and estimation of controller workload are examined in Sections 5 and 6, respectively. The design process is viewed as iterative, with the key constraints being upon the availability and qualifications of control personnel.

SECTION 2. TRAINING OBJECTIVES

The basic goal of simulation-based training is to allow members of the command group to acquire the skills necessary to operate smoothly within the time and resource constraints they should expect in battle. Ideally, the conduct of each training exercise is guided by explicit training objectives which specify who is to be trained, what tasks they are being trained to perform, under what conditions the tasks must be performed, and what criteria or standards indicate successful task performance. The development of simulation systems for command and staff training must be guided by an analysis of the range of training objectives for which the system might be employed.

The systems-approach-to-training (SAT) focuses on the critical tasks that must be performed to achieve minimal proficiency. SAT is sometimes criticized as being an incomplete approach to training because of this focus: it does not emphasize the factors that distinguish true expertise from acceptable competence. For any given group of people who achieve acceptable task performance in a SAT-based training system, there will be a few individuals who are considered outstanding at their job, a larger group who are considered average, and some who are marginal. It has been contended that close study of how exceptional performers do things differently in command and control may lead to the identification of a teachable set of battle management skills that could provide much richer training objectives. Command and control researchers are beginning to investigate these issues. It remains to be seen whether the results could best be applied as additional selection criteria, as improved training techniques, or as decision aids. In the near term the SAT approach is the only viable alternative.

In this section, several implications of the analysis of training objectives are addressed. First, the analyses produced by the Army Training and Evaluation Program (ARTEP) are discussed, and suggestions are made for developing additional detail about objectives. Next, some considerations are presented about the definition of the training audience. Finally, the view is presented that training objectives should be considered during scenario development, and that scenario specification should be facilitated by the simulation system.

ARTEP: Tasks, Conditions, and Standards

The ARTEP manuals contain lists of training objectives which include tasks to be performed, conditions under which the tasks are performed, and standards which should be achieved. The lists have been developed for commanders and staffs at various echelons and for various unit types.

The tasks specified by the command-staff ARTEP manuals focus on the products that should be produced by various staff elements (e.g., estimates, plans, orders, reports) and to a lesser extent upon the procedures they should follow in producing the products. Often, the ARTEP manuals list tasks that the command group must accomplish, without indicating which staff section or which individual should carry out the tasks.

The conditions listed for performance of ARTEP tasks focus almost exclusively on missions and tactical situations. Several aspects of command group training which a simulation should be designed to accommodate are neglected. A few examples include training to deal with incomplete, unreliable, contradictory, and incorrect information and intelligence; to operate under time pressure; to conduct extended operations requiring the use of separate shifts; to continue operations with the loss of one or more key staff members; to continue operations with the loss of a tactical data system; to recognize and deal with deception; and to make decisions under conditions of fatigue, noise and discomfort. Some obvious implications of this partial listing of additional conditions are that the training system should be designed to operate for extended periods of time, and that it should provide for filtering and modification of ground truth information from the simulation. From these examples, it should be clear that an expanded view of training conditions can provide useful design criteria. Conditions will be discussed further in sections 4 and 5.

The standards for performance comprise the third aspect of training objectives. ARTEP standards for command and staff functions tend to be vague and somewhat general (e.g., accurate, timely, responsive, etc.). In order to provide for measurement of progress and assessment of training needs, these standards must be supplemented. This issue will be considered further in Section 3.

Despite their limitations, the command staff ARTEP manuals are the best available source of information on what the training objectives of command group training should be, although they include some objectives which are better suited to training in field exercises than in command post exercises.

To be of use to simulation training system developers, the ARTEP task lists must be screened for inappropriate objectives. They also must be expanded to include detailed descriptions of the procedures involved in task accomplishment and an assignment of individual and group responsibility. It would be useful to trace the interrelationships among tasks and subtasks, as this information will facilitate the subsequent development of measurement procedures. The actual conditions under which the task might have to be performed still need to be specified because the ARTEP analysis is limited to general situations, i.e., missions, in which the tasks are performed. Finally, the standards must be made more precise and measurable.

Training Audience

A typical error which occurs when determining who must be in the training audience is to include too many people. Attempting to train the entire command group tends to include personnel in the training audience simply to simulate the performance of minor functions that are rarely required.

In research involving 12 battalion command staffs (Kaplan, 1984), ARTBASS participants were asked to select training objectives from a list of 52 potential objectives and, after the exercise, to rate how much they had learned about each of the objectives selected. ARTBASS proved to be an effective trainer for the S3, commander, S2 and FSO, but trained only half of the objectives selected by the S4, while the S1 reported that he learned little about

any of his objectives. The relative inequality of training across staff positions is by no means limited to ARTBASS but is a general feature of battlefield simulations. Partly the problem is the result of exercises which begin with a scenario in which the forces are not yet engaged and the units are fully manned and equipped. Those in combat and combat support functions can begin work immediately while those in combat service support (CSS) functions have little to do during the initial period. Even beyond this source of inequality, however, the simulation systems usually provide less challenging tasks, less varied activity, and fewer problems for the CSS sections.

Previous attempts to deal with this inequality of training opportunity include the development of off-line manual simulations to be played in conjunction with the automated system, e.g., ADMINMOD and LOGMOD for CAMMS, the use of probe messages to stimulate activity in administrative and logistics areas, and the development of medical and maintenance simulations in BABAS. In the case of the FSO, expansion of the training audience to include fire direction center personnel dramatically improved the realism of his training.

When determining the training audience, the quality of the activity the players perform must be considered. Simply because a player is kept active during the exercise does not guarantee a training benefit. A division chaplain may receive messages about soldiers who need counseling or a veterinarian about meat which may be contaminated. This will give them something to report at the end of the day but does not provide them training in how to counsel soldiers or inspect meat. In contrast, the G3, during the exercise, is able to make plans and practice his job. **When deciding who will be included in the training audience, particularly in high echelon simulation systems, it should be determined whether the person will perform his function in a simulated exercise or will merely simulate performance of his function.**

Scenario Development

The scenario used in command group training is the principal means of control over the exercise. The basic situation, the activity of the opposing force, the intelligence available and the resources under the control of the training audience must be carefully selected to insure that all training objectives selected for a particular exercise are addressed. Ideally, a battle simulation system should be flexible enough to exercise any scenario consistent with the training objectives. In practice, current automated systems are limited by the available graphics and terrain modeling data (either videodisk images or Defense Mapping Agency data), and further limited in terms of the types of opposing forces for which data exists. Although a small set of standardized scenarios is usually developed in conjunction with a battle simulation, primarily for operational testing purposes, existing simulation systems provide very limited support for scenario development or modification. The support that does exist consists primarily of databases describing typical U.S. and opposing force (OPFOR) units, along with software for creating modified unit descriptions and task organizations. Since scenario development is extremely labor intensive and requires a high level of expertise in large unit operations, the lack of support in automated systems for this process has had the unfortunate side effect of concentrating most command staff training on a few well known scenarios.

Although development of training scenarios is currently something of an art form, with little existing documentation on what should be included or on how the situation can be modified to meet particular training objectives, enough is known about the process to recommend the incorporation of tools to relieve the scenario developer of some routine labor. In particular, terrain analysis can be relieved of much tedium by incorporating automated line-of-sight fans and three dimensional perspective views of the terrain. Similarly, sensor placement, weapons positioning, and indirect fire coverage for the OPFOR can be assisted by the use of range fans. Doctrinal templates of OPFOR scheme of maneuver and defensive tactics can be provided to assist the scenario developer in choosing initial positions and avenues. Many similar tools have already been developed for use with analytical wargames (McGrew, 1980). Scenario development would be greatly facilitated if the simulation is based upon a "systemic" wargame, i.e., one which is capable of operation for extended periods without controller input. The systemic model could be run to test scenarios to insure that appropriate force ratios are used. Further, the wargaming capability could be used to develop information on how well a unit might be expected to perform under the given conditions (SAIC, 1985).

SECTION 3. DEVELOP PERFORMANCE MEASUREMENT

Performance assessment has tended to receive insufficient attention when battle simulation systems are designed and when they are employed. This is especially unfortunate because the value of the training received is inextricably linked with the quality of feedback presented. Research by Thomas, Barber, and Kaplan (1983) shows that explicit incorporation of measurement and feedback in simulation-based command and control training exercises is essential for effective training.

The requirements of performance measurement and feedback need to be considered early in the design process or even minimal system support may be precluded. The system must provide the hardware for collecting, storing, processing, and disseminating performance data. Also, the software should be designed in such a way as to facilitate the collection of data on battle outcomes, status, resource usage, and other information associated with training objectives. With the advent of operational tactical data systems, the opportunity for on-line collection and analysis of staff performance data has increased dramatically, provided that the linkage of the simulation system to the tactical data system is appropriately designed.

Performance measurement can be addressed at several levels of the command staff environment. One classification scheme is to consider heirarchial levels of: (a) command post or system, (b) major subsystem, (c) staff element, and (d) individual. Different indicators or "observables" are characteristic of measurement at each level. Statistics summarizing the outcomes of the simulated battles are useful at the system and major subsystem (e.g., maneuver, fire support, air) level. Products and procedures are associated with evaluation at the staff element level. Knowledge and decisions require individual level measurements.

This discussion will cover basic measurement considerations and review successful measurement techniques for each type of measure. Automated measurement techniques and their associated data and resource requirements will be emphasized.

Battle Outcome Statistics

This category includes most of the standard operations research techniques for judging the outcomes of analytical wargames, such as loss-exchange ratios (LERs), surviving maneuver force ratio differentials (SMFRDs), and combat power ratios. It also includes indicators of the efficiency of an operation such as consumption of supplies in various logistics categories. Research performed by Thomas (1983) showed that, of the most widely used measures of this type, only SMFRDs accounted for a significant proportion of the variance in expert judgment of mission accomplishment for a set of training exercises.

In subsequent research (Thomas & Cocklin, 1983), a panel of experts evaluated outcome measures from a large number of covering force operations and assigned mission accomplishment scores. A weighted linear combination of SMFRDs, measures of territory lost, time the enemy was delayed, and accuracy of

intelligence estimates at the conclusion of the mission accounted for a much higher proportion of the variance in mission accomplishment judgments than SMFRD's alone. The regression model was applied to a new set of training exercises, and was extremely accurate in predicting the mission accomplishment judgments of the same panel of experts. Further development, including extension to other missions and validation against a larger sample of expert judgments, is required before the regression models could be used to replace human evaluation of mission accomplishment.

Despite the experimental demonstratic: of how battle outcome statistics can be used to provide reliable indicators of performance, they are not sufficient to evaluate staff performance. There are a number of reasons for this.

First, there exists considerable doubt as to the accuracy of the underlying models of combat which provide the attrition results. This is particularly true of models which use firepower score methods to estimate the relative ability of a unit to inflict casualties on an opponent, because firepower scores ignore the differential effectiveness of various weapons systems against targets of varying "hardness". To some extent, there is also distrust of more sophisticated attrition methodologies if they are being used in conjunction with unclassified weapons effects data.

Second, the raw numbers provided by battle outcome statistics are meaningless in themselves. They must be compared to standards of performance which describe how well a unit would be expected to perform a similar mission with similar assets against a comparable opponent. These data do not currently exist; they cannot be reliably obtained from training environments due to the variability of such exercises in unit composition, training goals and methods, and scenarios played; and they cannot be generated using current analytical wargames due to the inherent speed limitations and lack of replicability of man-in-the-loop simulations.

Third, such data are not a pure reflection of the performance of a commander or staff. Outcomes are also influenced by the behavior of friendly controllers, data entry personnel, and the opposing force controllers. Current training simulations do not automate the decision making of subordinate, support or opposing elements, but rely upon very detailed model inputs provided by training support personnel who are often too busy to provide appropriate inputs (Thomas & Solick, 1982).

Finally, measurement based on battle outcome statistics is not well-suited to the primary purpose of command-staff training, which is to diagnose and correct performance deficiencies. This purpose is better served by measurement approaches which directly examine the tasks a staff performs, the way in which they do it, and the products resulting from their effort.

As a design issue, the use of battle outcome statistics as performance measures increases requirements for simulation fidelity, storage and analysis of detailed records, and development of supporting techniques to acquire normative data against which training results can be compared.

Products and Procedures

The staff element is the intermediate level in the process heirarchy, and indices of staff performance primarily involve either products or procedures. Products include items such as estimates, plans, orders and reports. Measures of the products can be on dimensions of timeliness, accuracy, understandability, relevancy and completeness. Procedures involve whether actions and products were developed in accordance with prescribed doctrine or Field SOP.

Observation has been the only technique commonly employed for evaluation of staff products and procedures during simulated battle. It is usually done informally, relying upon the participants and training support personnel to take note of key events, apparent misunderstandings, and failures to coordinate plans. These impressions are commonly reviewed in a debriefing session at the end of the exercise (ENDEX), known as an after action review (AAR). The AAR is usually supplemented by a brief summary of the status of forces at ENDEX. In simulation systems which provide replay capabilities, locations, status, and activities at key points in the battle are reviewed as the participating commander and chief controller remember them. Occasionally, these informal techniques are augmented by the presence of one or more special observers who may record their observations and evaluations using an ARTEP task list or other mnemonic such as a list of key information to be presented in the operations order (Olmstead, Baranick & Elder, 1978b). Some simulation centers have also instrumented their simulated Tactical Operations Center (TOC) facilities with video monitors and centralized communication systems to improve the effectiveness of observers.

There are at least two opportunities for designing battle simulations to improve this rather haphazard approach to performance assessment. First, the computer system can be given a list of key events to look for which indicates common failures in planning and coordination. This list can be used to focus an automatic replay on instructive situations or be provided as input to a more traditional AAR. Examples of such events include routing supplies through your own minefield (indicating failure to coordinate resupply and barrier plans), sealing off one of your own units with FASCAM[2] (indicating failure to coordinate maneuver and fire support), and cancellation of air strikes due to smoke or dust over the target area (failure to coordinate air support and indirect fires). These and other more subtle failures in planning or coordination can be noted by simulation software without relying upon an observer being in the right place or recalling events that happened several hours earlier.

The second area of opportunity exists when the staff being trained in a battle simulation environment is equipped with a tactical data system (TDS) or with equipment which simulates the functionality of such a system. The TDS can be equipped with a "watchdog" program to note and record usage of the system for later comparison with normative or doctrinal data stored on the training device. The types of events that might be of interest include the number and time of submission of reports required by SOP, the categories of information

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2

Family of scatterable mines. FASCAM may be implaced by artillery, by air, or by surface vehicles.

accessed by each staff section during preparation of plans and annexes to the operations order, the frequency with which status reports are requested, and the delay in entering information received via voice communications.

There has been some experimental use of testing methods with staff products and procedures. The testing involved variations of probe methodology, where a message is inserted into the information flow of the exercise specifically to generate some required staff action so that the type, quality, and timeliness of the staff response can be noted (Carter & Patton, 1985). This differs from purely observational methods in that the situation is deliberately altered, sometimes in rather artificial ways, to generate behavior that would not ordinarily occur in a "free play" exercise. Examples of such probes include jamming of communication, report of a chemical weapons attack, looting reports, etc. A number of such probes were developed for use in manual simulations.[3]

Battle simulations may support the probe technique by storing a list of probe messages and prompting controllers to insert them into the message flow to the TOC at specific times or in conjunction with the occurrence of specific events in the simulation. If the probes are designed to generate some required staff activity on a tactical data system (TDS), the technique can be tied in with the previously suggested watchdog program to provide automated assistance in observation of responses and response times.

Staff products and procedures are the major emphasis of command post training exercises. As such, they should also be the primary focus for automated measurement procedures.

Knowledge and Decisions

The individual performance level is divided into knowledge and decision categories. Since knowledge is not directly observable and only the results of decision making can be directly observed, measurement of individual performance must rely upon: (a) test techniques to determine whether the individuals have the knowledge they should, and (b) judgments of the quality of decisions. The assessment of decisions requires speculation about how alternatives would have worked out; the effectiveness of a set of decisions is seldom determined. Typically observers will only note when a decision varies from accepted practice or from what they would have done in the same circumstances.

The most successful application of testing to determine knowledge is based on information flow methodology (Kaplan, 1980, 1981). This is a technique for tracing the spread of specific items of information throughout a staff group during planning, preparation and delivery of an operations order. It requires a prior analysis of the types of information that each staff section or subordinate element should receive on the plans, resources, and activities of other staff elements. When the mission is briefed to the staff group undergoing

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3

Probes used with manual simulations were intended only to exercise staff areas, e.g., administrative and logistics functions, that were not well supported by the simulation techniques employed. When combined with an observation plan, they are also useful for measurement.

training, these test elements of information are presented individually to different staff sections. After the staff plans and presents its operations order, they and subordinates are given a written test on the items they received initially, the items they should have received through coordination or in the operations order, and on other items that were inserted but not directed to them, i.e., items that they were not required to know to perform their individual functions.

Attempts have been made in experimental situations to extend the information flow method to the mission execution phase of exercises (Thomas, Barber, & Kaplan, 1984; and Thomas, Kaplan, & Barber, 1984). Knowledge was tested in each staff section by requests from appropriate controllers. Specific queries were directed to key staff members in the experiments by Thomas, et al, rather than introducing significant events and tracing the spread of information throughout the staff as proposed by Carter and Patton (1985). The limitation on this technique is on the number of seemingly random queries that can be instituted without interfering with the attempt to maintain a realistic battlefield situation. In the cited studies, 5-6 queries per staff element were inserted. This number is too low for any statistical conclusions to be drawn about individual performance, but the numbers aggregated across staff elements could give fairly reliable indications of a staff group with problems in internal coordination.

Another approach to determining the accuracy and timeliness of distribution of information was explored in several exercises. It was assumed that the information posted on the various situation maps maintained by different staff sections was an indicator of the knowledge held by the staff. By sampling that information periodically and comparing it to the "ground truth" information taken directly from the battle simulation, one could obtain data on the timeliness and accuracy of information dissemination. In practice, the technique did not work. The basic practical difficulty was in obtaining information posted on the maps and analyzing it in time to be useful for feedback to the command group. Another difficulty was in interpreting the results obtained. There is currently no doctrine for how much timeliness or how much accuracy is enough. In results from a division level exercise, it was clear that the working answer varied widely across staff sections. It would be costly to assemble enough normative data using manual techniques to permit interpretation of these numbers.

Though the testing methods used to evaluate knowledge were successful in experimental tests, they are impractical to implement due to the amount of manpower required. This suggests another design criterion for battle simulations: they should provide automated assistance in initiating performance tests, in collecting performance data, and in analytically developing standards for performance, particularly in the area of evaluating decisions. Two techniques are suggested here that require attention in the design of new battle simulations: a comparison of the state of the model with the state of the staff's knowledge, as represented in the data base of a TDS, and the development of wargaming methods for assessing alternative decisions.

The first technique proposed is essentially an automation of the comparison of the "ground truth" in the model with information "posted" by the staff in their TDS. If implemented appropriately, however, it can go well beyond a simple comparison of location and status information. For example, if the staff is required to formally post estimates, these can be analyzed computationally and compared to the "real world" in the model.

The second technique, analytical wargaming, is an extension of the previous proposal for generation of normative data on outcome measures. If wargames are to be used for comparison of alternative decisions, they must provide an explicit representation of decision making. To minimize the influence of controller activities on the training exercise results, the model used to drive the training system should also operate in a systemic fashion. Thus we recommend that the same basic model should be used for both purposes to simplify the comparison of alternative decisions.

Very fast systemic models of the type needed are currently under development by Training and Doctrine Command Analysis Center (TRAC) (viz. the VIC -- Vector In Commander -- model) and under the auspices of Defense Advanced Research Projects Agency (DARPA), where Corps Battle Analyzer (CORBAN) is being implemented on an experimental parallel processor. Current results indicate that VIC will run ten times faster than real time, in contrast to slower than real time operation for man-in-the-loop versions of analytical models. The first parallel version of CORBAN is sixty times faster than its implementation on a standard serial architecture. These results indicate that this technology may soon become a practical design alternative for training simulations.

SECTION 4. DEFINE SIMULATION REQUIREMENTS

There are two fundamental questions to be answered in defining requirements for a training simulation: (a) what to simulate, and (b) how to simulate it. Ideally, the answer should flow directly from an analysis of training objectives; specifically, who is to be trained, on what tasks, under what conditions and to what standards. In practice, neither the state-of-the-art in modeling, nor in task analysis have permitted such a straightforward translation of requirements. Previous simulations for training have been designed upon the basis of what modeling techniques and computer resources were available, with an implicit assumption that controllers could use manual simulation or role-playing techniques to fill in the gaps. This evolutionary approach to system design has had some unfortunate side effects. These will be discussed under four categories: model fidelity, software maintenance, exercise preparation, and control of training conditions. Suggestions will be presented for more closely approximating the desired relationship between training objectives and system design.

Model Fidelity

General requirements for fidelity in a training simulation include the ability to portray those missions that might be realistically assigned to the unit being trained; the availability of all major resources that might be under the control of the unit; the ability to portray realistic restrictions on resources and activities imposed by terrain, weather, competition for scarce assets, equipment and personnel limitations, and the ability to portray realistic timing of activities, for example, movement, coordination, set-up and breakdown times, planning and implementation time required by subordinate and support elements. Comprehensive listings of the resources and activities that should be portrayed in staff training are available in Miller and Bonder (1982) and Michel and Solick (1983).

Discussion of some common omissions in developing systems is provided in Thomas and Solick (1982). For battalion and brigade level training systems, nuclear and chemical contamination, sensor systems, movement of artillery and air defense assets, counter battery and counter mortar fire, electronic warfare, construction time for obstacles, maintenance of equipment, and medical problems were usually not included in models. Since then various features from this list have been added to developing simulations, but none of the current training systems have incorporated all of the previous omissions.

Two additional fidelity issues impinge directly upon the scope of the model and the size and type of equipment needed to accommodate it. First is the level at which to simulate subordinate units. The standard answer is two echelons below the level of the training audience. While this answer is adequate for maneuver units, it can lead to an underestimate of the number of entities to be modeled, and thus potentially to a selection of inadequate equipment and to a bottleneck in data entry. In the development of specifications for the Corps Battlefield Simulation (SAIC, 1985) it was determined that certain highly specialized support elements required modeling at the company or platoon level. This roughly doubled the number of entities to be modeled.

A second basic fidelity issue is whether the training system is to operate on classified or unclassified data. Cost to incorporate electronic shielding and to provide secure communications is usually contrasted with the perceived benefit of obtaining realistic combat results, particularly if the results are to be used for performance evaluation. Briefly, there is no evidence that this factor makes a difference in training. Other considerations, such as whether the system is intended to exercise classified scenarios, will override training benefit issues.

The basic lesson learned in the development of models to support training is that maneuver and direct fire conflicts do not constitute a combined arms training system. The modeling effort and system resources required for indirect fires, air and air defense, intelligence and logistics, is at least as great as that required for maneuver. If medical or maintenance functions are to be included with sufficient fidelity to provide training in the performance of those functions, each of those areas will require similar resources to the foregoing. Failure to take these factors into account has led repeatedly to a system design that required extensive modification (e.g., MACE/BABAS) or to an unworkable concept (e.g., the distributed CATTS system and CAMMS II were both incapable of accommodating the required volume of messages over phone lines to a central processor). For the systems that have been fielded despite a neglect of combat support and combat service support functions, there have been consistent complaints from the field that they require an unrealistically large number of controllers to manually portray the neglected functions (Thomas & Solick, 1982; Barber & Solick, 1980; Kaplan & Barber, 1979; and Barber, McGrew, Stewart, & Andrews, 1979) and that they fail to address many of the training objectives of the principal staff members (Kaplan, 1984; Kaplan, 1985; and Kaplan & Fallesen, 1986)

Software Maintenance

The evolutionary approach to the design of battlefield simulations has tended to neglect many issues that affect the system's success as a home station training device.

Continual changes in equipment, system capabilities, and doctrine for force design require that a training system be designed for continual revision. It is fairly straightforward to include in the initial design of the training system provisions for programmatic changes that will occur during its design life, such as new weapon systems. However, incremental improvements in speed, range, accuracy or resource consumption of systems frequently require data base changes after a training system is developed and fielded. The need for change also arises as new data become available on lethality or vulnerability and as new means are developed for employing existing equipment. Forecasting such changes based upon current experience with design modifications can minimize the disruption in fielding training devices by providing excess computational and storage capacity in the original design. **It is essential to have comprehensive documentation of the system for such cases, including documentation of the relationship between software models of processes and associated control staff activities, such as data entry, model output interpretation and role playing tasks. Model maintenance is considerably easier if a structured**

design technique, e.g., JSD/JSP (Jackson, 1983), is used to prepare a simulation for implementation and if modular programming (e.g., ADA, Modula-2) or object-oriented programming (e.g.,ROSS, Smalltalk, LOOPS, Flavors) is used for the implementation (Pressman, 1982).

Exercise Preparation

Preparation for a training exercise includes development or selection and modification of a scenario tailored to the unit's training objectives, adaptation of a generic data base to the specific forces included in the scenario, and preparation to carry out the plan developed by the training audience. Preparations also include training of support staff to operate the equipment, to plan the exercise in accordance with training objectives, and to play the roles of higher, subordinate, and adjacent headquarters. Current simulations usually provide one or more standard scenarios, a suggested program of instruction for controllers, and user manuals which list control functions. The most recently fielded training system, ARTBASS, also includes computer-assisted instruction on operation of the computer system. In general, however, little is provided in the nature of tools for scenario development for data base modification in accordance with doctrinal templates, for planning an exercise to meet training objectives, nor for instruction on playing the role of other headquarters elements (Kaplan, 1985).

A complete system design should include these considerations, since the cost of such preparations approach the cost of conducting the actual training exercise (Kaplan & Barber, 1979). Furthermore, it may not be most effective to consider them as low-cost add-ons to be designed later, as the equipment selected for the exercise may not provide the most appropriate input and output devices for these other system functions. For example, mouse input devices are useful for high-speed menu selection, but not as good as graphics tablets for entry of detailed graphics such as avenues of advance, phase lines, or control measures. Similarly, optical scanning or bar-code readers might be best for setting up a unit data base, but not for initiating resupply actions (Monk, 1984).

Control of Training Conditions

Design of simulations to accommodate varying training conditions is usually interpreted strictly in tactical terms, e.g., varying geography/terrain, varying weather conditions, accommodating different unit types, or varying missions and combat ratios. While these factors have been shown to strongly influence simulated combat results (Thomas & Cocklin, 1983) they are not closely related to measures of the products (plans, estimates, reports) that staff members produce nor to measures of the extent to which they follow accepted procedures (Thomas, Barber & Kaplan, 1983). In order to directly manipulate the difficulty of staff tasks, a training simulation must be able to provide control of message loads, amount and accuracy of information and intelligence, integrity of communications links, and other factors directly influencing information processing and decision making. Control of such factors is important if training is to be tailored to the level of skill of the staff since a major goal of the training program is to create command groups capable of functioning smoothly under adverse conditions. A "How to Train" manual should be produced which documents the objectives that the system can support, the resources needed to

conduct training exercises, the ways in which exercises can be tailored to specific deficiencies, and the ways in which the system supports performance measurement and feedback. This manual should address the composition of the intended training audience and the ways in which supplementary training can be provided to those members whose function is only marginally supported by the simulation. The "How to Train" manual should be included as on-line documentation for the system to synchronize the maintenance of software and documentation, to permit more rapid dissemination of changes, and to provide on-line assistance in resource calculations and scheduling of training events.

SECTION 5. DEFINE CONTROLLER TASKS

Defining the tasks performed by the training support personnel lies at the heart of the design process. Controller tasks must be explicitly defined in order to: (a) delimit the performance requirements of the simulation, (b) design the interface between the controller and the simulation and the interface between the controller and the players, (c) estimate the system manning requirements, and (d) develop the supporting documentation and training manuals.

In current simulations there are three fairly distinct classes of training support personnel: the controllers, the interactors, and the role players. Controllers include dedicated simulation center personnel to handle functions that require detailed knowledge of the training system and, in some cases, members from the training audience's parent headquarters to oversee the unit training. Interactors perform primarily clerical tasks, entering data at the direction of controllers and role players and calling up displays and status reports. They provide the training to role players on the system capabilities and limitations. Role players portray elements with whom the commanders and staff must interact. They often serve in their actual duty position; translating orders into activities that can be entered into the computer; directing their own (simulated) subordinates; and providing orders, information and intelligence to the training audience.

The discussion here will focus on the control functions that must be performed and the system requirements for interfacing with these functions. The emphasis will be upon identifying and making design provisions for control tasks that minimize the required number and qualifications of support personnel. Three general areas of controller functions will be discussed in this section: controlling the exercise, controlling the model, and role playing.

Controlling The Exercise

The exercise control function encompasses the planning, preparation, monitoring, and evaluation of the exercise. Control personnel function as trainers insofar as they control the conduct of the exercise, the conditions to which the training audience is subjected, and the planning of performance evaluation and feedback. To respond to observed strengths or deficiencies of the trainees, controllers need to adjust the conditions and course of the battle to present appropriate training opportunities. Also, controllers may be responsible for performance measurement, using probes, measures, observing staff performance, marking key events for emphasis during after action reviews and coordinating with other controllers.

Setting Training Conditions. It has been observed that insufficient provisions are made for adjusting the conditions under which the command staffs train (Fallesen, Lussier, & Garlinger, 1986). In a given exercise, controllers may wish to change the difficulty of the exercise by increasing the tempo of battle, removing key personnel suddenly, or jamming communication equipment. Command groups need both to train on conducting a battle which follows prepared plans and to react to sudden events just as in actual battle.

Sometimes the command group should receive clear and accurate intelligence from above and below, and at other times their information should be vague and distorted. In short, simulation systems need to be flexible enough to allow play under a wide variety of conditions (Olmstead, Baranick, & Elder, 1978a). The choice of conditions should depend on the entrance level of training of the unit, the specific training objectives of the exercise, and on the course of play during the exercise. System developers need to be aware of this controller function and provide methods to put the control of training conditions in the hands of the controllers. Systems should be adaptive to the performance of the command group, recognize areas in which more training is necessary and guide the play of the exercise in a manner which presents the appropriate training opportunities (Shaket, Ben-Basset, Madni, & Leal, 1979). **Training systems must be designed with sufficient flexibility to allow adaptive control of conditions.**

Evaluating Performance. Another overall responsibility of controlling the exercise is evaluation. Evaluation tasks have been performed by interactors as well as controllers and infrequently by independent observers without other control tasks. The measurement of the performance of the command staff was covered in section 3 of this report, but it cannot be overemphasized; the presentation of useful feedback is critical to the success of the exercise. Not only must the feedback be accurate, it must be accepted by the training audience. This means that controllers participating in evaluations must be able to support their conclusions, ideally through an objective system of performance measurement.

An after action replay function and combat outcome summaries are both techniques designed to assist in providing feedback. Neither, however, explicitly identifies the specific strengths or deficiencies of the training unit. Without further development of a performance measurement technology, these methods do not allow an effective assessment of the command group. However, the incorporation of performance measurement techniques will also impose additional tasks upon the training support staff, additional requirements for training controllers to perform these tasks, and additional control staff coordination requirements. These considerations must be included in the workload and system manning analysis.

ARI is conducting research in the area of command staff performance measurement and will be able to provide more specific assistance in the future. At present a few basic suggestions can be made. First, the controller workload should not be so heavy as to prohibit the possibility of measurement and evaluation functions. Second, there should be some provision made for the presence of evaluators, to include the ability to view events occurring in the model, traffic on the communication nets, and activity of the training audience. Third, no matter how rudimentary, a start must be made on providing automated assistance to the measurement problem. The system could be designed to identify and flag occurrences from a previously identified set of typical errors at a given echelon, to request staff products, to prompt controllers to insert specific behavioral probes, and to request that the controllers input evaluative information at critical points during the exercise.

Controlling The Model

Model control involves the translation of the directives of the training audience into commands for entry to the computer and control of the operation of the battle models. The tasks can be as tedious as arranging for the movement of a battalion, platoon by platoon, and as creative as simulating the effects of resources which are not modeled, e.g., achieving the same effects as a demolition team through "phantom" airstrikes.

The controllers must be able to implement the orders of the commander and staff without major discrepancies or omissions and must do it without lengthy delays. Imagine, for example, that troop movements were achieved in an accurate and timely manner, but either engineer operations or fire missions were greatly delayed or altered. Such a situation frustrates the training audience as it destroys the synchronization of their forces and the effectiveness of their plans.

A primary purpose of any training exercise is to identify deficiencies in the behavior of the training audience. The commander and staff, however, typically find it very easy to see the deficiencies of the system and very difficult to see their own faults. Some tolerance for interactor error exists and can be considered as "fog of battle." It would be better, however, if this "fog of battle" effect was intentional and was guided by the training objectives. As indicated above it is sometimes desirable to conduct training under the conditions of a perfectly efficient set of simulated subordinate units while, in other cases, a less efficient group of "subordinates" would be better to train the monitoring and directing aspects of command and control. In any event, when the controllers cannot effectively control the model, it is almost certain that the training audience will see the model/interactor difficulties as an excuse for all the problems of the exercise.

In part, the solution involves greater attention to the design of the interactor-computer interface, and a strong commitment to human factors engineering (Monk, 1984). Prior to design of the user interface, system developers should develop a list of criteria and consult with human factors experts on how the desired performance may be attained. Basic issues to consider include sharing of displays, color versus monochrome display requirements, multiple displays versus multiple windows, and use of iconic and nomographic techniques. Attention should be given to:

- Providing a clear, easy-to-learn (self teaching) network of commands and menus without employing abstract coding.

- Using formats and terminology which are natural to the military user.

- "Bombproofing" data entry techniques so that the user is not allowed to make irreversible errors.

- Allowing recovery from error which entails a minimum of reentry.

- Extensive employment of feedback, acknowledgements of instructions, prompts, and warnings.

- Use of an appropriate set of input devices and creatively designed software to minimize workload.

- Highlighting of critical or urgent messages and actions.

A second avenue of approach to the goal of reducing the model control tasks is through more extensive automation. Using operations research or artificial intelligence (AI) techniques, the computer can assume increasing amounts of the control workload (Shannon, 1975, Barr & Feigenbaum, 1982). An example is the current ability of some systems to employ route optimization routines. Control of the opposing force is particularly open to AI application because there is no requirement for communication or coordination with members of the training audience.

The design goal must be to reduce the model control tasks to an absolute minimum, in terms of both physical and mental workload. Requirements for computer expertise must be reduced to the point that controllers drawn from the unit being trained can operate the equipment and can translate computer output into tactical messages after a brief training session. Workload reduction will reduce the number of controllers required by eliminating those who perform only data entry functions, will reduce controller training time, and will free controllers to perform other valuable tasks. Realistic goals must be set for the size of the control staff and for the amount of exercise preparation required. The additional analysis and software development costs this approach entails will be recovered through increased efficiency in conducting training.

Because units must train as they would fight, future battle simulation exercises will need to incorporate tactical data systems such as the Maneuver Control System, which is being fielded at echelons from battalion through corps. The introduction of tactical data systems to command and staff exercises has the potential to significantly reduce the controller's model control workload. Information will need to flow between the players and the computer in both directions, with the results of the computer modeling process automatically updating the tactical data system's database, and command group directives helping to control the operation of the model. The role playing workload may also be reduced by automatic generation and digital transmission of periodic reports required by field SOP (SAIC, 1985).

In summary, the tasks for controlling the model need to be reduced to a minimum. If the tasks are too numerous, time-consuming or complex, the training effectiveness of the system will be greatly impaired. Representation of battle events should not be at a level of detail below that necessary to present a realistic picture to the training audience. If the representation is much beyond the minimum necessary, controller workload may suffer. Finally, simulations need to be designed so that the link with tactical data systems at least eases the controller workload rather than intensifies it. **Efforts to enhance the human factors design or to automate the controller functions are not frills but are vital given the conditions under which the systems are used in the field.**

Role Playing

Controllers must play the roles of key personnel in units which are higher, subordinate, and adjacent to the training unit. The role playing function serves to insulate the training audience from the computer and to allow training in required communications. Typically, subordinate unit commanders are played by people brought to the exercise by the training unit and are often the actual subordinate unit commanders. Occasionally, the higher headquarters assign personnel to the exercise to act in various positions from that headquarters. More often, however, controllers from the simulation center portray the roles of higher headquarters. While adjacent units need to be included in the scenario, it is rare to have role players in these positions; information normally obtained from adjacent unit commanders can be obtained from the higher headquarters role players without a significant loss of realism.

Subordinate Role Playing. Subordinate unit role players must keep themselves apprised of the tactical situation, manage simulated subordinate and support units in accordance with the plans and orders of the command group, and generate an information stream of realistic tactical messages based on the output of the simulation. The latter function is not well supported by the current generation of battle simulations. In particular, the output of automated simulations appears to compromise realism of the message traffic by providing too much military intelligence and not enough detail. For example, a sensor report might include a complete opposing force unit designation and an exact center-of-mass location, whereas a realistic report might provide an estimate of a number of vehicles sighted, type of vehicles, approximate location and direction. Role players are required to perform this translation. Preliminary results from work in progress at Fort Leavenworth ARI Field Unit indicates that this translation task is difficult to perform. The difficulty is compounded in the context of an exercise with the demands of the role player's other duties and the obligation to report to one's actual superiors.

One possible solution would be to automate the production of message traffic. This would insure that input to the training audience would accurately portray events in the battle, would not reveal unrealistic amounts of intelligence, and would conform to standard military format. The controller workload would also be reduced. It has been argued that the role players are receiving training benefit by composing the messages themselves, however, in the current circumstances this argument seems to have dubious merit. Taking ground-truth information and dirtying it up for transmission to the next higher echelon is not a task in which Army officers need training.

An alternative solution to the translation problem is to redesign the interface between the subordinate unit commander and the computer. Displays of ground-truth information could be avoided. Instead, at the subordinate unit commander stations (or other functional area stations such as log/admin, air, or fire support), the role player would have available only that information which he could normally be expected to have, either through the activity of his staff and subordinates or through first-hand observation. Current simulations have terrain appreciation capability that portray a 3-dimensional view from any location (McGrew, 1980), given that digitized terrain data is available. The

computer would need to supply a further description of what battle events the role player should see from the ground, and to provide displays of the information which should be available to the role player.

Although replacing ground-truth computer representations of the battle with a realistic interface between the role player and the computer would require a major software development effort, there would be many significant advantages:

- The training audience could be supplied with a realistic message stream which is generated in a natural manner.

- Errors by role players in portraying the situation would be reduced.

- Role players would receive practice in skills which more closely match their usual military assignments.

- The interface could be used to establish an effective simulation of the unit commander "going forward" to see the battle and personally direct subordinates.

Many of the controllers are in a position to receive considerable training benefit from the exercise. This potential can be realized by purposely designing the functions performed by subordinate elements of the command group to resemble, as much as possible, the tasks on which they are to be trained.

Higher Echelon Role Players. The role players portraying higher echelon personnel must work on the scenario development, present the initial briefings and operations order, coordinate with the various functional areas, and make decisions regarding the distribution of higher echelon assets and the dissemination of intelligence. Higher headquarters role players are usually one or more staff officers from the training unit's actual higher headquarters or are controllers who work at the simulation center. In the latter case, they may be called upon to portray positions with which they have little experience.

There are several areas in which the system might support the higher role players, for example, by aiding in scenario development, preparing specialized functional information packages, and by generating messages to be inserted during play. One observation concerning higher echelon play is that the role players provide much of the support of the higher echelon, i.e., providing intelligence and combat assets, but rarely make the demands of the higher echelon, i.e., additional taskings such as primary information requirements (PIR), other information requirements (OIR), or required standard reports (Thomas & Solick, 1982). The load on the training audience would be more realistic if additional requirements were placed by the higher echelon. The simulation could incorporate such taskings or prompt the role players to demand scheduled reports, increasing the requirements on the command group.

In summary, role play is an important aspect of the exercise and can mean the difference between a command group training in a realistic situation under realistic constraints and a command group which is merely playing a battle game against a computer. Neither the design of current simulations nor the training currently given to the controllers provides sufficient support for this important function.

Role playing must be more realistic than current practice. The message traffic to the training audience can be enhanced by automated production. An improved computer interface needs to present more realistic information to the role players in a more usable form. The higher echelon needs to be enhanced so all required reports and additional taskings are included.

Summary

In the past the model control task has received the major portion of attention in the design process. Not only is it necessary for the operation of the system but it is the function which designers naturally associate with the controllers. Role playing is recognized during the design phase, but it is generally given little or no automated support. Other controller functions such as controlling the exercise and performance evaluation typically are ignored completely until operational testing of the system. For battlefield simulation systems to be truly effective trainers, there must be a shift to increased emphasis on interacting with the training audience rather than constrained attention to the model.

SECTION 6. ESTIMATE CONTROLLER WORKLOAD

Simulation systems are developed in accordance with performance goals, which specify the required operating capabilities of the system, and staffing goals, which indicate the desired limit of operator and controller personnel. Working within the performance and staffing constraints, the system designer should compile a complete description of all the tasks performed by controllers, should apportion these tasks between individual controller positions, and specify the skill requirements for each position. The establishment of manning requirements is normally an iterative process, involving redesign until both the skill requirements and workload levels for each proposed controller position are reasonable.

The resulting estimates of the number of controllers needed and the description of tasks they must perform drive the hardware design requirements for controller workstations. In existing simulations, several controllers are assigned to each workstation with data entry devices and situation map displays usually shared by two or three controllers. The tradeoff between cost of equipment and efficiency of control must be considered. Cost has been the determining factor for existing simulations, but equipment costs have been reduced to the point that efficiency may now predominate. If model control tasks are distributed to the role players, it is preferable to equip each individual with his own input and display devices. It may be necessary to develop preliminary cost and staffing estimates for both approaches.

Complete, well-documented analysis of control personnel requirements is the exception rather than the rule in battle simulation development, primarily because of the evolutionary approach of incremental refinement to existing simulations. A notable exception is the requirements analysis performed for the Corps Battlefield Simulation (SAIC, 1985). The recommendations made in this report are primarily based upon that effort and upon lessons learned in the MACE Concept Evaluation Program (Thomas & Solick, 1982).

The process of determining manning requirements is presented in Figure 3. The initial step involves an analysis of the component processes of the model, in which a large and detailed list is compiled of all the functions, tasks and subtasks which must be accomplished in the training systems. Examples of such an analysis may be found in Miller & Bonder (1982). The task list should include all functions of the simulation, including the model control, role play, and evaluation functions.

Each of the subtasks must be allocated to either the controllers or the computer. In general, this allocation should be guided by a comparison of the human and computer strengths and weaknesses. The ability to make complex inferences, to find similarities, and to hear, speak, and understand are human strengths. The ability to store and retrieve large amounts of information and make fast and accurate calculations are computer strengths (Woodson, 1981). Further analysis of the tasks may be helpful in making the allocation decision (TRADOC PAM 351-4(T)). Some aspects of the tasks which may be considered are:

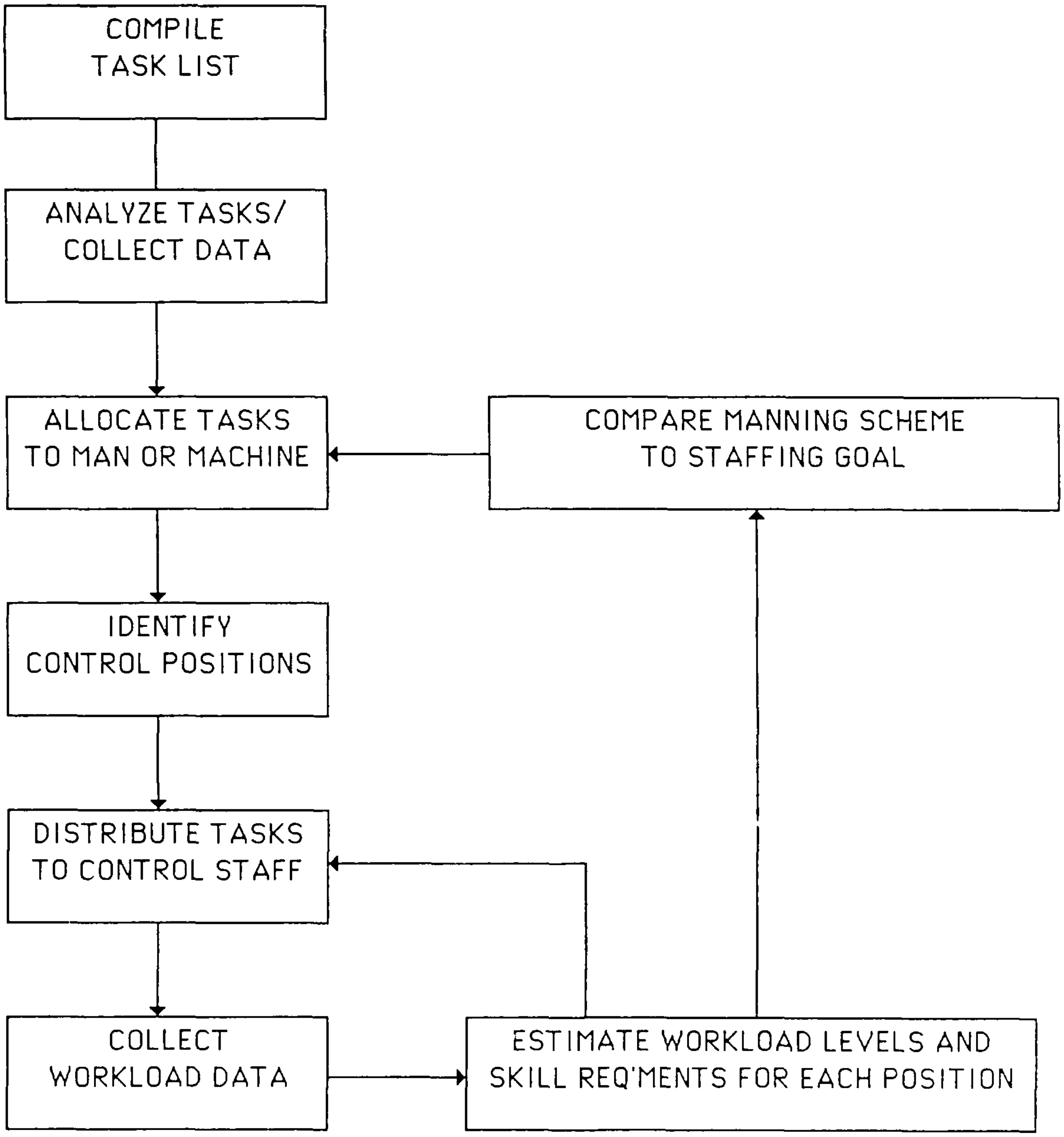

Figure 3. Steps in determining staffing requirements.

- The action performed - abstract the essential actions required.

- Skills required - differentiate between clerical activities and those which require judgment or perspective.

- Knowledge required - indicate the military knowledge required and what functional specialties might be necessary.

- Input required - identify the characteristics of the input requirements and source rather than the specifics of current practice. Indicate whether the information is gained "shortly" before or "long before" the task period begins.

- Output required - as with input, aim for the characteristics of requirements and destinations.

- Preceding activities - distinguish between the required events which precede task performance and those which make logical sense or are preferred but are not strictly necessary.

- Timing - tell when the task should occur, what kind of delays may occur, what time constraints exist, what are realistic delays. How frequently do tasks occur? Note tasks which must be performed concurrently.

- Potential difficulties - machine breakdown or backlog, controller overloading, etc.

- Potential errors - identify potential sources and the impact of errors.

Additionally, the functions concerned with evaluation of the training unit's performance need special consideration. The evaluation tasks are difficult and seem to require much human assistance. They also are tasks which can be ignored without "crashing" the exercise but are vital to attainment of the goals of the exercise. **Evaluation tasks need to be given sufficient machine support to insure that they receive the controllers' attention.**

Once the tasks to be accomplished by controllers have been analyzed, a preliminary list of controller positions can be established based on the staffing goal, on the functional specialities for role playing, and on the essential model control functions. The preliminary manning scheme is completed by taking each of the tasks required and assigning it to one of the proposed controller positions.

The manning scheme must be analyzed to discover weak points, where either the skill or workload requirements are too high. Two general principles should guide the analysis. First it is better to conduct experiments, observe current exercises, or use survey or historical data than it is to simply guess. Second, the estimates should be conservative, leaving sufficient margin for error. There will be tasks that have been overlooked, activity at peak levels which was not anticipated, and personnel who work with less than 100 percent efficiency or who lack skills.

One aspect of workload estimation which needs to be addressed is the frequency of occurrence of the tasks. This includes both the number of times the task is performed over the exercise (or per day) and the peak frequency, the highest rate at which the task must be performed. Estimation can be assisted by analyzing doctrinal material or unit SOPs or by observing current simulations. For example, message traffic for a controller position can be estimated by determining the number of SOP reports per transmission mode (voice, digital, or written) for that position and inflating the totals to account for non-SOP queries and replies. Observing actual exercises at that echelon may help to determine the percentage of SOP to non-SOP reports, the average duration of each transmission per mode, and the peak message rate. A similar analysis can be done for other events such as movement orders or fire missions. When using data from current simulations, it should be kept in mind that the data may not be ideal. They represent the best that can be done in the current generation of simulations and do not necessarily reflect appropriate levels for an accurate representation of battle.

Estimates must be made of the time required for controllers to perform each task. For data base entry and retrieval tasks, one of the best ways to accomplish this is to build a mock-up or prototype of the man-machine interface early in the design process. Experiments with the interface prototype will serve to both improve the design efficiency and provide workload estimates for the individual tasks. Additionally, potential data entry bottlenecks will be revealed. The interface tests should always be conducted with inexperienced personnel to insure that excessive controller requirements are not built into the system.

Besides contributing to the estimates of controller workload, measures of the time required to perform the various tasks are necessary to assess adequacy of the simulation. Most of the tasks can be considered time-critical, in that excessive delays will seriously impair the realism of the exercise. For example, when indirect fires are called for, either too responsive or too sluggish artillery action will provide unrealistic training conditions. In general, realistic delays can be built into the simulation where needed. Data entry bottlenecks, or other input delays in time-critical tasks, however, indicate that the interface must be redesigned for more efficient operation, more personnel must be assigned to the task, or that greater portions of the task must be automated.

The manning scheme can be assessed by considering each position, determining whether the average and peak workload levels and the skill and knowledge requirements are reasonable. The number of control personnel can be reduced by shifting tasks, combining role play with model control and evaluation tasks, "doubling up" of roles or making other adjustments to the extent that military knowledge requirements permit. The staffing goal needs to be met, of course, and also some survey of the units which will ultimately use the system must be made. <u>It should be determined whether the units are willing to provide sufficient numbers of persons with appropriate skill levels to support the exercise.</u> If it is determined that planned controller levels cannot be reached, the process must be iterated, starting back at the stage where tasks are allocated to the computer or the controllers and testing alternative allocations and task

designs. The analyses previously conducted, for example the prototype interface tests, should indicate which tasks are the most time consuming and where the greatest potential saving can be made.

SECTION 7. CONCLUSIONS AND SUMMARY RECOMMENDATIONS

This section recapitulates the main points of the previous sections. Most of the recommendations presented are consistent with the current evolutionary development approach, though increased emphasis is placed on analysis of the tasks of both the training audience and the training support staff.

Training Objectives

Collection and analysis of tasks, conditions and standards is a necessary precursor to development of a training system. The ARTEP manuals are a good starting place but further development of training objectives is necessary. Some personnel typically included in the training audience are not provided adequate training opportunities. It is recommended that a way to provide adequate training be found or these people be removed from the training audience.

Tools should be provided for development and modification of scenarios. Included with the tools should be on-line help facilities and documentation of how the tools should be used. If systemic wargaming is incorporated as proposed, the model should be adapted for testing and modification of scenarios.

Performance Measurement

Numerous recommendations were made in section 3 for various levels of support for diagnosis of deficiencies and provision of feedback. These include:

- Develop templates for instituting the information flow methodology, to be filled in with specific items of information from the scenario. Document the methodology and the sources of information in the data base that are to be used.

- Develop a list of probes, along with a means for automatically notifying appropriate controllers to insert them, either at pre-set times or in response to simulation events.

- Provide automatic detection of events based on common errors that indicate failures in staff planning or coordination.

- Develop normative data from model runs for interpretation of mission accomplishment data.

- Develop a watchdog program for the staff's tactical data system to track preparation and delivery of reports.

- Develop procedures to compare the ground truth data in the training system data base with the staff's picture of the battle as reflected in the tactical data system.

- Develop analytical wargaming procedures to evaluate alternative decisions.

Simulation Requirements

Beyond basic considerations of resources to portray, resource limitations, and level of detail (i.e., model fidelity) these additional areas were discussed:

a. Software maintenance was discussed as a basic factor in a system's success as a home station training device. Comprehensive documentation of the system and use of modular programming techniques were recommended.

b. The training system should be designed to minimize exercise preparation effort. Scenario development, controller training, and data base modification are among the most labor-intensive aspects of exercise preparation.

c. Emphasis should be placed on training to overcome obstacles to effective information processing and decision making. This implies that control is needed over message loads, accuracy of information, integrity of communications and other factors which directly affect the difficulty of staff work. A "How-to-Train" manual should be included as on-line documentation.

Define Control Tasks

Three general areas of controller function were discussed: exercise control, model control, and role play. Control functions required by various performance measurement techniques were discussed. These impose system requirements for communication among controllers, observation of the training audience and interfacing with various automated measurement techniques. Minimization of model control functions was recommended, either through development of a systemic model, through close attention to human factors engineering of the user interface, or through automation of low level, repetitive controller decision making functions. Additional support for role playing was discussed under two alternatives: automate production of message traffic, or design the simulation interface to supply the information that subordinate unit commanders would ordinarily have through observation and communication with their staff and their own subordinate commanders.

Estimate Support Staff Requirements

This principally involves setting realistic goals based upon availability of personnel at the field locations where the training system is to be used, analyzing both the workload imposed by the system and the military knowledge requirements for role playing functions and successively refining the system until it can be operated by the available personnel.

A preliminary design based upon current training systems can be used to detail all of the functions to be portrayed. These functions can be further described in terms of how the current design is intended to operate and in terms of what control functions will be required for the current design for model control, role playing, and evaluation.

Data on the number of simulation events (e.g., movements, fire missions, and air strikes), to be portrayed per unit time can be derived from current command post or field training exercises. Similarly, data on the number of voice and digital transmissions per unit time can be obtained. Average time per message can be directly obtained from the transmission data to estimate the average and peak communications workload for controllers.

To estimate model control workload, initial values can be obtained analytically, but for greater accuracy, it is recommended that a prototype of the interface to the simulation be created as one of the first steps in system development. Analysis of time and errors in the use of the interface can reveal potential data entry bottlenecks and areas of model representation that demand further automation before the simulation software is built. Performance tests on the prototype interface should use inexperienced personnel to insure that excessive controller training requirements are not built into the system.

Workload estimates from this preliminary analysis can be used to determine the minimum number of controllers required to perform role playing functions and the minimum number of additional personnel needed to meet model control requirements. This number added to the training management and evaluation staff is the minimum required by the preliminary design. To reduce the absolute number of people required, "doubling-up" of functions should be examined, adding model control tasks to role play and evaluation personnel and giving multiple roles to role players to the extent that military knowledge requirements will permit. A comparison to staffing goals will then probably indicate that further reductions are needed. The data from the prototype interface can be used to target the most time consuming functions for redesign.

Final Remarks

We recommend two radical departures from incremental improvement of existing systems. These are (1) base the simulation model upon a systemic analytical wargame and (2) begin development of on-line performance measurement techniques based upon the interaction of the training audience with a tactical data system. These steps are believed to be necessary to cope with the most critical shortcomings of current command staff training systems: excessive control personnel overhead and the lack of performance measurement capabilities.

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